Letters to the Editor

Note on Finite Amplitude Waves in Liquids*

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IN a recent paper,[1] the authors reported measurements on the attenuation of ultrasonic waves of finite amplitude in water in the frequency range from 4 to 9 mc, and at acoustic pressures up to 5 atmos. In these measurements the value of α/ν^2 (α= amplitude absorption coefficient, ν= frequency) increases with increase in the acoustic pressure. The rate of this increase varies with frequency, being greatest at the lowest frequency. Such a behavior is consistent with the theoretical treatment given by Fay,[2] as amplified by Lindsay,[3] but differs from the experimental results of Towle and Lindsay.[4]

Recently, similar measurements were reported by Zarembo, Krasilnikov, and Shklovskaia-Kordi[5] at 1.5 mc. These values confirm the idea that the slope of the α/ν^2 *vs* acoustic pressure curve increases as the frequency is lowered.

All of these results can be effectively portrayed in a single graph by plotting α/ν^2 as a function of p/ν, where p is the acoustic pressure. Such a graph is shown in Fig. 1.

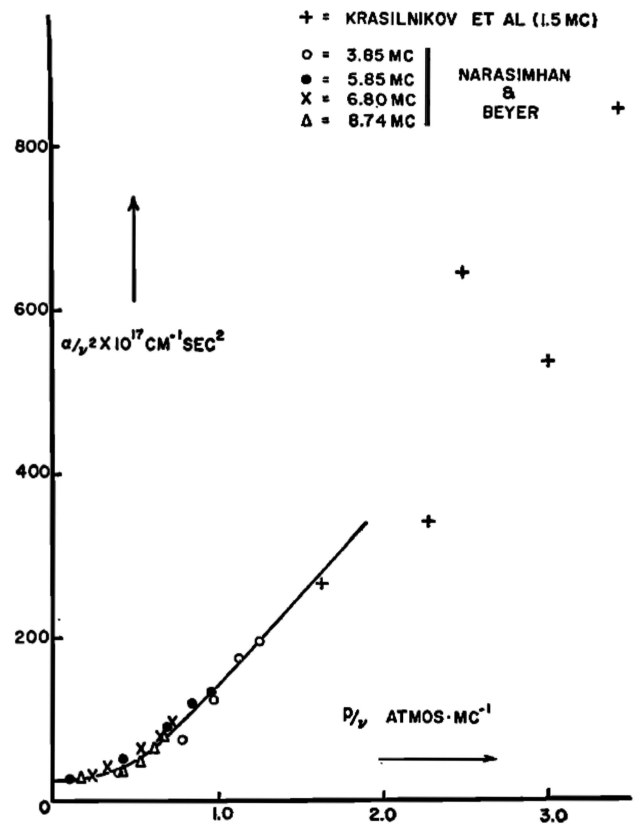

FIG. 1.

It can be seen from the figure that all of our data lie along a single curve, and the results of Krasilnikov and his co-workers, while they have greater experimental scatter, fit approximately the same curve. This agreement of experimental data would appear to establish clearly the frequency dependence of the absorption coefficient-acoustic pressure relation.

It is to be noted that this same type of universal curve cannot be obtained for the data recorded by the authors for aqueous solutions of acetic acid and manganous sulfate, presumably because of the presence of a relaxation frequency in or near the experimental range.

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1 V. Narasimhan and R. T. Beyer, J. Acoust. Soc. Am. **28**, 1233 (1956).
2 R. D. Fay, J. Acoust. Soc. Am. **3**, 222 (1931).
3 R. B. Lindsay (private communication to the authors).
4 D. M. Towle and R. B. Lindsay, J. Acoust. Soc. Am. **27**, 530 (1955).
5 Zarembo, Krasilnikov, and Shklovskaia-Kordi, Doklody Akad. Nauk SSSR **109**, 731 (1956); J. Acoust. Soc. Am. (to be published).

Simple Sound Source in a 50- to 300-Foot-Per-Second Air Stream

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IN jet-engine combustor research, it may sometimes be desirable to excite some flow field within a combustor with a train of sound waves. This is because some of the flow fields are unstable, and the sound can trigger the instability. A sound source is thus used as an instrument to search out unstable flame,[1] and as a mixer to increase heat release rates.[1,2] When the combustor is small, it is possible to use electronic equipment to produce the desired sound.[1] As the size of the combustor increases, it reaches a point where electronic drivers are no longer convenient. For such a combustor a sound source sustained by the approach flow is desired.

In looking for such a sound source the writer developed a way of terminating the open end of a tube so that the tube whistled for a wide range of angles of attack and flow velocities.

Figure 1 shows the shape of the tube mouth that gives the best performance. Variations of this shape resulted in either a decrease

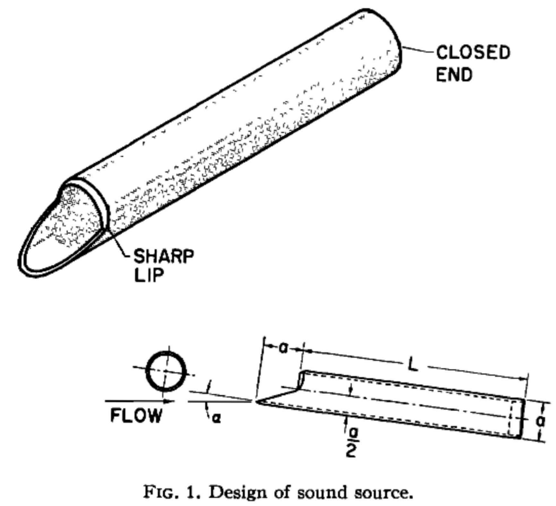

FIG. 1. Design of sound source.

in operating range (i.e., angle of attack and flow velocity at which the tube would whistle) or a decrease in sound emitted or both. Measurements taken by hot-wire anemometry and by microphone showing some of the whistle characteristics are included in Figs. 2 and 3.

The tests were conducted in an air free-jet. The sound levels (Fig. 2) were measured outside the flow by a microphone placed 12 inches downstream of the open end of the tube. Flow noises were filtered out. The particle velocity intensity (Fig. 3) is the fluctuating velocity u' measured at the whistle opening divided by the approach velocity; both values were obtained by hot-wire

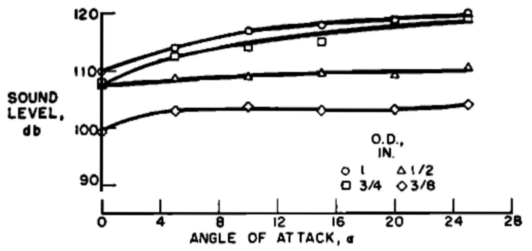

FIG. 2. Effect of angle of attack on sound level measured approximately 1 foot from source. $L=8$ inches; $U=250$ ft/sec.

anemometry. The sound level within the whistle appears to have reached 168 decibels at 300 ft/sec approach flow velocities.

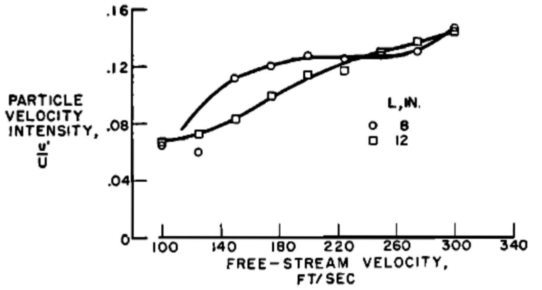

FIG. 3. Particle velocity intensity measured at open end of sound source. $a=\frac{3}{4}$ inch; $\alpha=20°$.

By using a sound source of this type it is now possible to excite unstable flow fields in large-scale combustors.

[1] Perry L. Blackshear, Jr., Growth of Disturbance in a Flame-Generated Shear Region, NACA TN 3830 (November, 1956).

[2] Blackshear, Rayle, and Tower, Study of Screeching Combustion in a 6-Inch Simulated Afterburner, NACA TN 3567 (1955).

Estimates of the Maximum Precision Necessary in Quantizing Certain "Dimensions" of Vowel Sounds

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Results of psychoacoustic experiments are used to estimate the greatest precision necessary in quantizing narrow band-width data specifying the vowel sounds of speech.

RECENT developments in the theory and application of digital techniques have stimulated interest in applying these techniques to certain systems for reducing the band-width and channel capacity necessary to transmit speech. Such an application raises questions concerning the resolution necessary in quantizing (or digitalizing) the "compressed" speech data. It is apparent that employing a resolution in excess of that required would serve to nullify the saving in band-width and channel capacity that the compression system might afford, while, on the other hand, insufficient precision would obviously impair the usefulness of the communication link.

In a voice communication system the speech information usually originates and terminates with a human operator. The perceptual abilities of man, therefore, determine the precision with which the data must be transmitted and processed. It is the purpose of this note to summarize some experimental findings which permit quantitative estimates of the maximum precision necessary in quantizing certain useful "dimensions" of vowel sounds.

"Dimensions" of vowel sounds.—Experimental and theoretical investigations in speech production[1-3] have shown that the acoustic output of a speaker during vowel production can be specified reasonably accurately in a relatively simple fashion; namely, by specifying the frequencies of the normal modes of vibration of the vocal tract and the fundamental frequency of vibration of the glottis. In the production of vowel sounds the natural frequencies of the tract always are manifested as gross maxima, or formants, in the amplitude spectrum of the acoustic output. The relative amplitudes of the spectral maxima bear specific relationships to one another, uniquely determined by the values of the formant frequencies.[4] During speech the formant frequencies and the fundamental vocal frequency change relatively slowly with time and hence constitute a narrow band-width specification of vowel sounds. For this reason these quantities are useful as information-bearing signals in certain band-width compression systems, sometimes referred to as "formant-coding" system.[5]

In some types of formant-coding systems,[6] it has been found expedient not to make use of the fact that the relative amplitudes of the vowel formants are uniquely determined by the formant frequencies. In these cases additional narrow band-width signals representing the relative amplitudes of the formants usually are transmitted.

If the formant concept is extended to consonant sounds it is no longer true that the formant frequencies uniquely determine the formant amplitudes. For consonant sounds, therefore, data on the relative amplitudes of the spectral maxima are more important than for vowel sounds.

For the purpose of the following discussion let it be assumed that electrical signals representing the formant frequencies, formant amplitudes, and fundamental vocal frequency are to be used as information-bearing quantities in a compression system. In order to compute the channel capacity required for the transmission of such signals it is necessary to know the precision with which the signals must be transmitted.

Perception of speech sounds: differential versus absolute discrimination.—It is probable that the perception of speech by man corresponds more nearly to an absolute judgment of acoustic stimuli than to a differential discrimination. Furthermore, it also is probable that the differences which are differentially discriminable in the vowel dimensions are smaller when the sound exists in an isolated quasi-steady state than when it exists in the more dynamic state characterizing connected speech. If these assumptions are in fact true, it would appear that differential discrimination tests performed with relatively steady-state stimuli should lead to estimates of necessary precision that essentially represent maximum values or upper bounds. Such estimates based upon differential discriminations should be very conservative figures when compared to the accuracies necessary for proper identification of vowel sounds. Experimental evidence on absolute discriminations performed along frequency and amplitude dimensions[7,8] indicates that the ability of man to make absolute discriminations is considerably less acute than his ability to make differential discriminations.

Results of psychoacoustic experiments.—On the basis of the foregoing assumptions, psychoacoustic experiments have been conducted to determine just discriminable differences (or difference limens) for certain of the vowel "dimensions." Most of the experiments have been pilot studies, considerably restricted in scope. In no respect can they be considered exhaustive. The experiments do provide, however, some quantitative data, albeit meager, in an area where none previously existed.

More specifically, experiments have been conducted on synthetic vowel sounds produced at conversational levels to determine difference limens (DL's) for the frequencies of the first and second formants[9]; the fundamental vocal frequency[10]; the amplitude of the second formant[11]; and the over-all vowel amplitude.[12] The gross results of these experiments are summarized as follows: (1) The DL's for formant frequency are of the order of $\pm 3\%$ of the formant frequency; (2) The DL for fundamental frequency (or "pitch") is of the order of ± 0.5 to $\pm 1.0\%$ for a vowel having a fundamental frequency in the neighborhood of 120 cps; (3.) The DL for second formant amplitude is of the order of ± 3 db, or